

METEOROLOGICAL PROBLEMS OF RIGID AIRSHIPS

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The growth of aeronautics has not only greatly increased interest in and use of meteorological information, but has laid before the meteorologist new problems, some of which he has never before considered of any great practical importance. The operation of rigid airships in particular brings up many conditions about which exact information is required. The following notes, submitted recently outline specifically some of the conditions which are of interest. Obviously, exact and permanent answers to these questions are impossible. Climatological data are never final. Studies are under way, however, with the view to obtaining information of the conditions outlined. General interest among meteorologists will no doubt bring to light much more information which up to the present time has not been published.

The weather conditions which interest the airship designer and the airship navigator most are gale winds, squalls, especially those not accompanied by clouds and precipitation, and sudden gusts. Given definite information of the intensity, extent, etc., of these conditions the designer and navigator can take the steps necessary to surmount their effects. Some of the subjects about which airship interests require more accurate information are:

(a) The maximum sudden changes in wind velocity likely to be encountered by airships. This refers to the probable greatest difference between the lull and peak of a wind gust within a few seconds and the frequency of occurrence of these conditions.

(NOTE.—The qualification "probable" or "likely" must be applied to these problems, because there is actually no *practical* limit to the intensity of the weather conditions which may exist. "Likely" and "probable" are taken to include all conditions which airships might be expected to experience at one time or another over a period of 5 or 10 years in regular and frequent operation over the "known" parts of the earth, excepting, of course, the very violent conditions such as tornadoes, thunderstorms, etc., which must be avoided by the usual precautions.)

There is at present considerable information and data available on the above subject and some data on subjects following, but information is not as detailed and accurate as is necessary, especially for design purposes.

(b) The maximum acceleration (rate of change) of wind velocity likely to be encountered while the wind direction remains constant. Also the frequency of occurrence of these maximum changes.

(c) The maximum change in wind direction likely to be encountered while the velocity remains practically constant. Also the frequency of occurrence.

(d) The maximum changes in both the wind direction and the wind velocity which are likely to occur at the same time. Also frequency.

(e) The maximum space rate of change in direction and velocity, that is, the maximum change in direction and/or velocity likely to be encountered within a given distance, say, a ship's length of about 800 feet.

(f) The minimum distance within which opposing vertical currents of a certain *critical* intensity are likely to be encountered. Also, the frequency. Or, the maximum net difference in velocity which is likely to be encountered within a horizontal distance of, say, 800 feet,

of two adjacent, vertical, *sustained* air currents. Especially, in clear air, or in air without the usual towering cumulus clouds which accompany violent convectional currents.

(NOTE.—The intensity of these conditions in well-developed thunderstorms is known to reach values which would be dangerous to the sturdiest aircraft.)

(g) The maximum difference in velocity and direction of two horizontal wind currents likely to be encountered within a vertical distance of 100 or 150 feet.

(h) The horizontal and vertical extent and the "thickness" in each of the above cases, of wind accelerations exceeding a certain critical value. (These, in order to determine the practicability of circumnavigation.) Also their persistency, in length of time; that is, the total period of their existence.

(i) The rapidity with which the foregoing large discontinuities in wind can develop and die out.

In all of the above cases, the conditions needing attention are those which are sustained for an appreciable length of time; that is, for more than a fraction of a second. The conditions should be investigated separately for surface and for upper air. The limits in these different regions will not only be different, but the methods of meeting the conditions on the ground will differ from those in the air. The relative intensity and frequency at various altitudes is important. These conditions need to be studied for different regions, because some regions are more favorable for the formation of violent conditions than are others.

WHENCE COME COLD WAVES?

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The literature on the place of origin of cold waves is rather extensive; nevertheless it must be admitted that beyond a general belief that the polar regions are the ultimate source of supply of cold air, little definitive evidence on the subject is at hand.

The explanation of the occurrence of both cold waves and warm waves is to be found in a better knowledge of the N-S component of motion in the atmosphere. It is a matter of common knowledge that the movement of warm air from low to high latitudes is not continuous in the sense that an uninterrupted flow takes place. Because of the fact that cyclones and anticyclones, the two phenomena most directly concerned in the interzonal circulation, are more or less ephemeral, in the sense that they lack continuity of movement across the earth's surface due to changes in environment or what not, uninterrupted flow is not possible. Warm air is transported poleward through the medium of cyclones. The current of warm air, however, may be cut off from the source of supply and then the cyclone, in the nomenclature of the Norwegian school of meteorologists, is said to be "occluded" and soon disappears; generally, but not always, a fresh cyclone is formed a few degrees eastward and southward, where a new current of warm air takes up its journey poleward. This is the principal reason why an uninterrupted passage is impossible; as a matter of fact, there are so many gradations in the volume and speed of movement in both directions, N-S, and the reverse, that it is quite impossible to treat the subject in a detailed way.

In this paper the chief emphasis will be placed on the large variations of pressure and temperature in an attempt to correlate changes in those elements with subsequent weather in the Temperate Zone of the Northern Hemisphere.

A fall in temperature in mid-latitudes and thus the coming of a cold wave is to be expected to the rear of a moving cyclone in winter; the amount of the fall in temperature being conditioned in large degree by the size and intensity of the cyclone. The amplitude of the fall also is more or less dependent upon the intensity and orientation of the anticyclone which immediately follows the cyclone. If the anticyclone be in the form of an elongated ridge of high pressure, places to the eastward of the ridge will experience northerly winds and a greater degree of cold than would obtain if a ridge of equal magnitude were oriented in an east/west direction.

It is suspected that polar air makes its way Equatorward along certain channels which by reason of topographic or other conditions offer the most favorable opportunity of southward flow. Thus I may express the belief that the Mackenzie Basin of North America is the most favorable and probable channel for the flow of polar air Equatorward; the eastern slope of the Canadian Rockies also is a favorable channel. Severe cold may be experienced without the anticyclone plotted on the daily weather map being in visible contact with truly polar air, and thus it has come about that the terms "polar" and "tropical" air are used in a relative sense; indeed, it can be easily shown that what appears to be tropical air to-day was yesterday truly polar air.

Another difficulty in the study of the problem is in the fact as stated by Sir Frederic Stupart, Director Canadian Meteorological Service, as follows:

In other years the North Pacific cyclonic areas appear to be of such intensity that they force their way into the continent in high latitudes and actually prevent the formation of anticyclones and their concomitant low temperature.¹

In this paper I have tried, without success, to make contact between the results of the international polar meteorological stations of 1882-83 and the network of meteorological stations in the Temperate Zone of North America. Although the result was a negative one, some interesting conclusions came out of the study and to relate these must be considered as warrant for printing this article.

The stations used and their geographical coordinates are given below:

	North latitude		West longitude	
Point Barrow.....	71	27	156	15
Fort Rae.....	62	38	117	43
Fort Conger.....	81	44	64	45
Jan Mayen.....	70	59	8	28
	East longitude			
Bossekop.....	69	57	23	15
Nova Zembla.....	72	22	52	30
Sagastyr.....	73	23	123	45

The observations at Fort Conger covered the period, August, 1881, to August 8, 1883; those at Point Barrow, November, 1881, to August, 1883, while those for Fort Rae and most of the remaining stations covered a 12 or 13 month period, August, 1882, to August, 1883, both inclusive in most cases.

Inasmuch as the three stations first named were separated from each other by distances ranging from 1,200 to 1,500 miles and by greater distances, except in the

case of Fort Rae, from the nearest stations in the mid-latitudes of North America, it was impossible to bridge the large gaps that existed. I was therefore reduced to the alternative of examining the records of the polar stations for internal evidence of large outbreaks, if any, of polar air which might be connected with known meteorological conditions in temperate latitudes. In these latitudes an outbreak of cold northerly air is evidenced by a sharp fall in temperature and a correspondingly sharp rise in pressure and the direction of the wind is almost invariably from north or northwest; in the polar regions, however, cold winds may come from an easterly as well as a northerly quarter.

I have taken out the interdiurnal, or day-to-day, pressure variations for each of the polar stations as being in some measure suggestive of large outbreaks of polar air passing over the station. Inasmuch as the observations were published in extenso, these variations are most easily obtained from the 24-hour daily means of atmospheric pressure. The average daily variation for each month of the year is shown in Table No. 1 below:

TABLE 1.—Average daily variability of pressure in thousandths of an inch

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Point Barrow.....	0.241	0.154	0.196	0.144	0.087	0.077	0.098	0.116	0.153	0.096	0.177	0.172	0.143
Fort Rae.....	.195	.160	.196	.181	.124	.125	.086	.122	.168	.121	.196	.200	.156
Fort Conger.....	.169	.193	.195	.173	.102	.087	.104	.086	.128	.100	.137	.143	.135
Jan Mayen.....	.220	.205	.189	.201	.118	.083	.083	.098	.157	.142	.173	.142	.147
Bossekop.....	.213	.220	.257	.131	.092	.080	.073	.102	.083	.116	.116	.161	.137
Nova Zembla.....	.194	.177	.215	.113	.156	.105	.103	.081	.170	.176	.146	.148	.149
Sagastyr.....	.133	.130	.137	.116	.114	.173	.098	.094	.146	.138	.163	.175	.135

The interdiurnal variability of pressure has been investigated by several writers, all of whom agree that it is greatest in high latitudes and regularly diminishes thence with approach to the Equator, where it is least.

The chief cause of the greater variation in high than in low latitudes is doubtless the larger contrast in temperature which obtains on the two sides (east and west) of the cyclone in those latitudes. It appears, however, that latitude alone is not the single controlling factor, since the variability is least at Fort Conger, the station having the highest latitude, and it is also small at Sagastyr, the station having the second highest latitude. An additional factor in the causation of large variability of pressure at high latitude stations is the occurrence of cyclones of great intensity that occasionally prevail in high latitudes.

The pressure records of the Point Barrow station show that that station is more frequently visited by intense cyclones than might be supposed. The fact that deep cyclonic systems approach the Alaskan coast of the Bering Sea area from the winter pressure minimum of the Aleutians makes it not only probable but certain that at times an intense cyclone passes eastward along the coast of northern Alaska. One such passed close to or over the station on January 12, 1882, having a central minimum pressure of 28.266 inches and winds of hurricane velocity.

Four days later the most severe windstorm in the life of the Fort Conger station was experienced. The two stations are about 1,200 miles apart, and a travel on the part of the cyclone of but 400 miles per day would accomplish the journey.

The range of the pressure at high latitude stations exceeds an inch in the months when the sun is absent and amounts to about three-quarters of an inch in the

¹ British Association for the Advancement of Science, Toronto meeting of August, 1924.

warm months. While there is abundant evidence of sharp changes in the barometer in high latitudes, evidence of similar changes in temperature is lacking.

The records of Fort Conger show five occasions in February, 1882, when a minimum temperature of more than 60° below zero Fahrenheit was registered, three of the five occurred with rising and the remaining two with falling pressure. The conclusion seems unavoidable that during the long polar night sudden temperature changes rarely or seldom occur. There are cases of slowly falling or rising temperature that persist throughout 8 or 10 days, but the large sudden changes so characteristic of midlatitude stations are rarely, if ever, experienced in the Arctic.

Sverdrup² has shown for that part of the Arctic Basin between 155° and 175° east longitude and about 75° north latitude, that the layer of cold surface air is shallow, less than 150 meters in depth; that above this cold layer is an inversion layer of about the same depth; and that above the last named the temperature increases slowly or remains constant to an altitude of 500 to 1,000 meters, where a new decrease begins.

The evidence of large daily rises and falls in the daily mean pressure will now be examined as an indication as to whether or not cyclones are frequent along the rim of the polar basin. The only available station that can be said to be within the basin is Fort Conger, and possibly the Sagastyr station.

I have selected the cases of largest daily rises or falls in the 24-hour mean pressure at each of the stations, taking as the upper limit of rise and fall 0.39 inch, practically 10 millimeters, and as the lower limit 0.20 inch, approximately 5 millimeters. The result of the count is given in Table 2 below.

TABLE 2.—Data on individual cases of large rises and falls in pressure. Number of rises and falls and ratios at the stations named

	Rises		Falls		Ratio of large and medium rises to falls of the same magnitude	
	0.39+	0.20-0.38	0.39+	0.20-0.38	Large rises	Medium rises
Point Barrow.....	6	41	13	38	1:2	1:0.93
Fort Rae.....	11	50	10	44	1:0.9	1:0.98
Fort Conger.....	4	34	7	32	1:1.75	1:0.91
Jan Mayan.....	15	40	11	42	1:0.7	1:1.05
Bossekop.....	10	30	12	27	1:1.2	1:0.9
Nova Zembla.....	9	42	16	26	1:1.8	1:0.6
Sagastyr.....	5	33	8	38	1:1.6	1:1.1

From the above it will be noted that large *falls* in pressure are about twice as numerous as rises of the same magnitude at Point Barrow, Fort Conger, and Nova Zembla, and that large rises and falls are about equal at Fort Rae and Jan Mayan. The next lower group of changes occur with about the same frequency regardless of the sign of the change; if anything the rises slightly outnumber the falls of the same magnitude.

The greater frequency of large falls in pressure as compared with large rises of the same amount is doubtless due to the well-known tendency of the barometer in a cyclone to sink to a lower level, using the normal as a point of reference, than it rises in an anticyclone. It may also be pointed out that the deflective force of the earth's rotation in high latitudes is considerably greater than in mid-latitudes.

CONCLUSIONS

In conclusion it may be said, for North America at least, the evidence of the three international Polar

stations is against the idea that aperiodic thrusts of cold air Equatorward take place, and that even under a more favorable distribution of reporting stations than now exists it would be difficult to identify any particular thrust with a subsequent cold wave in temperate latitudes. The cold waves of the latter region, if we may express a belief based on many years experience with the daily weather charts, are doubtless due to an initial southward movement of air which takes place in accordance with the pressure distribution of the moment, most probably about north latitude, say, 60° to 70°, but not necessarily within the polar basin, plus the effect of intense radiation from the snow and ice-covered surface of the continental interior.

The evidence of the Fort Rae station—a station situated, if not within the place of origin of cold waves, yet very close thereto—is adverse to the concept of an outbreak or thrust of cold polar air Equatorward. The speed of the wind at that station on the average of the three winter months is but 1.8 meters per second (4 miles per hour), and high winds are conspicuous by their absence. During the coldest days of the months, November to March, the prevailing wind direction was NNW., although it was calm and equal number of hours. The next most frequent wind direction was SSE., or in the exact opposite direction. The winds from the last named were equally cold with those from a northerly quarter, thus indicating a thorough mixing of the lower layers and a sort of equilibrium temperature after a day or so of northerly winds. Although the Point Barrow station is 18° farther north, the temperatures registered thereat are somewhat higher than at Fort Rae in the cold season.

It is quite probable that cold waves entering the North American Continent by way of the Mackenzie River Valley may have had their place of origin in extreme northeastern Siberia, in the valley of the Anadyr River. A movement thence to western Alaska is but a short journey and almost wholly over a land surface.

I am unable to discover satisfactory evidence of the movement in a northeasterly direction of offshoots from the winter anticyclone of Siberia; when that anti-cyclone is in its normal position, the course of offshoots is then southeast over the Sea of Japan and thence to the Pacific.

For Asia and Europe the problem is simpler; the region in which the international polar stations were located is separated from the northern border of the network of meteorological stations in Europe and Asia by a relatively narrow zone, and it should not be difficult to correlate the two sets of observations. The spread of cold waves in Europe and Asia has been studied by Von Ficker,³ from whose work it may be inferred that the origin of cold waves in Europe-Asia is within or along the rim of the polar basin.

Von Ficker⁴ groups the cold waves of Europe-Asia in three classes as follows:

(a) In this group cold air flows from a region of low air temperature in Asiatic Russia, practically in all directions. The relations in this group are comparatively simple although the type is of infrequent occurrence.

(b) In this group cold air first appears in the coastal region of the Kara Sea, to the eastward of the Ural Mountains, or in the lower valley of the River Ob, and spreads thence in a complicated way.

(c) In this group cold air first appears on the coast of the Kola Peninsula and spreads thence southeast and east toward Europe and Asia.

² Sverdrup H. U. The North-Polar cover of cold air, MONTHLY WEATHER REVIEW 53:471-75.

³ Ficker, H. von, Sitzungsber. Ak. Wiss. Wien, vols. 119 (p. 1769) and 120 (p. 745).

⁴ Loc. cit.